THE DESICCATION OF ROTIFERS

D. D. WHITNEY

COLD SPRING HARBOR, LONG ISLAND, N. Y.

THE general statement often found in text-books that "Adult rotifers can survive prolonged desiccation and resume active life when again placed in water," seems to have been made without sufficient warrant.

While working with the rotifer, *Asplancha brightwellii*, my attention was repeatedly called to the fact that when the water became sufficiently evaporated so as to expose only a portion of the body of the rotifer to the air it never recovered when placed again in a larger quantity of water and soon died. Doubt as to the truth of the general statement regarding desiccation naturally arose and in consequence a series of experiments were carried out to test the matter.

Forty-five species of rotifers that were collected in the various ponds and pools in the vicinity of Cold Spring Harbor, New York, were dried at room temperature, from a few hours to several days, during the months of July and August. They were dried without being exposed to direct sunlight in a hollow ground slide, upon filter paper, in sediment taken from the water in which the rotifers lived, and also in sediment mixed with sand. Masses of the water plants, Lemna, Myriophyllum and others among which many species lived were also dried. After the water seemed to have been completely evaporated fresh spring water was added and those animals that ever revived did so within ten to twenty minutes after the water was added. Drying the rotifers in masses of sediment and in sediment mixed with sand was found to lead to more recoveries.

In all experiments many species were dried in the same lot and in nearly all of them these were mixed with rotifers which were known to withstand drying. If none of

the animals revived when water was added it was assumed that the method of drying of the lot was imperfect but if, on the other hand, those animals that were known to be able to withstand drying revived, when water was added, the method of drying of the lot was deemed satisfactory. It may be possible, however, that the individuals of different species, since they vary greatly in size and form, require different methods for being successfully dried and again revived. But if revival after desiccation is of general occurrence for adult rotifers the various methods of drying used in the experiments ought to have given a fair percentage of positive results.

The individuals of some of the species were obtained in countless thousands, either in nature or in artificial cultures, others were less numerous and only a few thousand or a few hundred individuals were obtained. In a small number of species only a few individuals were found and used in the experiments.

Jennings[1] classifies the rotifers in five orders: (1) Bdelloida with two families; (2) Seisonacea with one family; (3) Rhizota with three families; (4) Ploima with eighteen families; and (5) Scirtopoda with one family.

In the experiments performed no individuals were used belonging to the order Seisonacea which contains all marine forms, nor were there used any individuals of the order Rhizota which contains all the fixed forms, Representatives were used from one family of the order Bdelloida, from fifteen families of the order Ploima, and from the one family of the order Scirtopoda. Thus the forty-five species used represented seventeen of the twenty-one families in the three orders just mentioned.

The following species were used in the experiments:

Order 1. Bdelloida.
Family 1. Philodinadæ.
Species. *Rotifer vulgaris*,[2] *R. macrurus*,[2] *Philodina roseola*,[3] *P. citrina*.[3]
Order 4. Ploima.
Suborder 1. Illoricata.

[1] AMER. NAT., Vol. XXXV, p. 725.

Family 1. Microcodontidæ.
Species. *Microcodon clavus.*[4]
Family 2. Asplanchnadæ.
Species. *Asplanchna brightwellii.*[3]
Family 3. Synchætadæ.
Species. *Synchæta tremula,*[5] *Polyarthra platyptera.*[2]
Family 4. Triarthradæ.
Species. *Triarthra longiseta.*[3]
Family 5. Hydatinadæ.
Species. *Hydatina senta.*[3]
Family 6. Notommatadæ.
Species. *Taphrocampa saundersiæ,*[4] *Notommata* ———,[5] *Copeus pachyurus,*[5] *Furcularia gracilis,*[2] *F.* ———[4] *Eosphora aurita,*[3] *Diglena* ———.[5]
Suborder 2. Loricata.
Family 1. Rattulidæ.
Species. *Mastigocerca mucosa,*[2] *M. bicornis,*[2] *M.* ———.[5]
Family 2. Dinocharidæ.
Species. *Dinocharis tetractis,*[4] *Scaridium longicaudatum,*[5] *S. endactylotum.*[5]
Family 3. Salpinadæ.
Species. *Salpina eustala.*[2]
Family 4. *Euchlanidæ.*
Species. *Euchlanis dilatata,*[5] *E. triquetra.*[4]
Family 5. Cathypnadæ.
Species. *Cathypna leontina,*[4] *Distyla gissensis,*[2] *D. stokesii,*[4] *Monostyla lunaris,*[2] *M. bulla,*[2] *M. quadridentata.*[2]
Family 6. Coluridæ.
Species. *Colurus bicuspidatus,*[5] *Metopidia lepadella,*[2] *M. triptera,*[2] *M.* ———.
Family 7. Pterodinadæ.
Species. Pterodina patina,[4] *P. reflexa.*[4]
Family 8. Branchionidæ.
Species. *Branchionus bakeri,*[5] *B. urceolaris,*[3] *B. pala,*[2] *B. angularis,*[3] *Noteus quadricornis.*[5]
Family 10. Pleosomadæ.
Species. *Pleosoma truncatum*[2] (?).
Order 5. Scirtopoda.
Family Pedalionadæ.
Species. *Pedalion mirum.*[2]

[2] Few thousand individuals used in the experiments.
[3] Many thousand individuals used in the experiments.
[4] Probably less than a hundred individuals used in the experiments.
[5] Few hundred individuals used in the experiments.

This list is far from being complete but it represents so many families of the free swimming rotifers upon which the general statement in regard to desiccation is supposedly based that the results obtained ought to indicate whether the phenomenon of desiccation is widespread among the common forms.

Philodina roseola and *Philodina citrina* were the only forms of the forty-five experimented upon which could successfully withstand desiccation and resume normal activities when again placed in water. Some of them remained ten days in small masses of débris, 1–2 mm. in diameter, which were as thoroughly dried as possible in the laboratory atmosphere. Those that were dried in the sun never revived when again placed in water. This may have been due to a too complete desiccation or to the high temperature, which was usually about 45° C.

The cuticle in the Philodinadæ is less specialized in the structure than in any of the other families of the three orders, and as this structural character is of great importance in the present system of classification the family may be considered the lowest or most primitive of all the twenty-one families. It is interesting to note, however, that some of the species of another genus, Rotifer, of the same family, can not withstand complete desiccation. In several experiments in which the four species of Philodina and Rotifer were mixed together in the débris, sediment or water plants, all four species would revive if the material in which they were contained was not completely dried, but only the two species of Philodina revived when the drying was complete. Systematists separate the two genera by the position of the eyes but evidently there is a more fundamental difference than this which means life and death in times of drought.

The common misconception regarding desiccation may probably have arisen, in part, from the fact that when mud or sediment from ponds in which rotifers live is dried living rotifers appear after a few hours when water is added to the sediment. These living rotifers prob-

ably develop however from the "winter eggs"; thick shelled fertilized eggs, which in some cases are known to withstand prolonged desiccation.

During this summer some winter eggs of *Asplanchna brightwellii* and *Hydatina senta,* which had been laid in June, were kept in water taken from the culture[6] jars until August 3. Then they were taken out with a little sediment and allowed to dry. On August 5, the sediment was apparently thoroughly dried. On August 10 spring water was added and at the end of twenty-four hours several small Asplanchna were swimming about in the water. Later young Hydatina were found in the water. The eggs seem to vary much in the length of time required for them to hatch, some not hatching for three or four days after being placed in spring water while others hatch within twenty-four hours. This may be due to differences in the rate of rapidity in which water penetrates the egg membranes. In sections of the winter eggs of *Hydatina senta* it is very noticeable that the thickness of the outer egg membrane varies greatly in different eggs.

On August 4 ten to fifteen cubic centimeters of mud and sediment were collected in a finger-bowl from the pond in which *Asplanchna brightwellii, Branchionus urceolaris,* and *Pedalion mirum,* were living and allowed to dry in the sun. The next day the mud was thoroughly dried so it would readily crumple between one's fingers. In this condition it was kept until August 10 when the finger-bowl was filled with spring water. On the following day several individuals of each of the above three species were swimming about in the water.

When ponds and pools in which rotifers live are in the process of drying up the water becomes so foul by the decomposition of dead plants and animals that all the rotifers of some species die before the pool is completely dried. If, on the other hand, rotifers are kept in the laboratory in very clean water which is allowed to slowly

[6] *Jour. Exper. Zool.,* Vol. V, p. —.

evaporate they all die, presumably of starvation. It is also interesting to note that some pools do not become dry during the summer but the rotifer fauna changes completely several times during the season. A small pond in this vicinity was teeming with *Asplanchna brightwellii* and *Branchionus urceolaris* during the early part of July but by the middle of August not an individual of either species could be found in it. Individuals of Pedalion and Polyarthra were very numerous at this time but in the latter part of August not one could be found. The pond was now teeming with *Branchionus angularis, B. pala* and *Triarthra longiseta* but no individual of the first four species named above was present.

In a case like this desiccation could play no part in the preservation of the species and they could only be saved by winter eggs.

Some winter eggs of *Asplanchna brightwellii* which were laid in June in artificial cultures were buried July 3 in an ice house upon a cake of ice where the temperature was 1–2° C. On August 7 they were removed from the ice house to ordinary room temperature and the old culture water replaced by fresh spring water. At the end of forty hours several young Asplanchna were swimming about in the water.

Many other winter eggs which were laid at the same time as the above lot but which had remained in the laboratory at room temperature in a bottle containing water, taken from the culture jar in June were placed in fresh spring water. In many cases within an hour the thick outer egg membrane had cracked open and exposed about a fourth of the thin inner membrane which surrounded the embryo. The history of some of these eggs was followed and it was found that they produced normal young animals on the following day. The swelling and cracking open of the thick outer membrane is obviously due to the sudden great change of osmotic pressure which is

brought about by removing the eggs from a somewhat foul and cencentrated culture to fresh spring water.

This process of causing winter eggs to develop in the summer is very likely the same that occurs in nature in the spring months. During the fall and winter the pools become free from abundant animal and plant forms and the accompanying products of decomposition by the frequent floodings by rains and the low temperature. In the spring the heavy rains flood the pools again and the osmotic pressure of the water is so much lower than it was in the previous summer that the eggs absorb water enought to rupture the thick outer membrane and stimulate the embryos to growth. As the temperature becomes favorable they develop and the life cycle is completed.

From the foregoing observations it seems probable that desiccation of the adult rotifers followed by revival is not of widespread occurrence in the group and is not the means resorted to by most species for tiding over unfavorable periods. Survival is due in most cases to the winter eggs which can withstand both desiccation and a low temperature.